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**Allen**

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(54) **CONNECTOR**

(56) **References Cited**

(71) Applicant: **Brantner & Associates, Inc.**, El Cajon, CA (US)

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(72) Inventor: **Mark D Allen**, San Diego, CA (US)

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(73) Assignee: **BRANTNER & ASSOCIATES, INC.**, El Cajon, CA (US)

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(65) **Prior Publication Data**

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Jenkins, David, "Utilizing Pressure Balanced Oil Filled (PBOF) Hose Cable Assemblies with Electric and Fiber Optic Connectors" *IEEE* (2008): 1-3.

International Search Report, International Application No. PCT/US2014/047483, International Filing Date, Jul. 21, 2014.

**Related U.S. Application Data**

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*Primary Examiner* — Jerry Blevins

(51) **Int. Cl.**  
**G02B 6/36** (2006.01)  
**G02B 6/38** (2006.01)

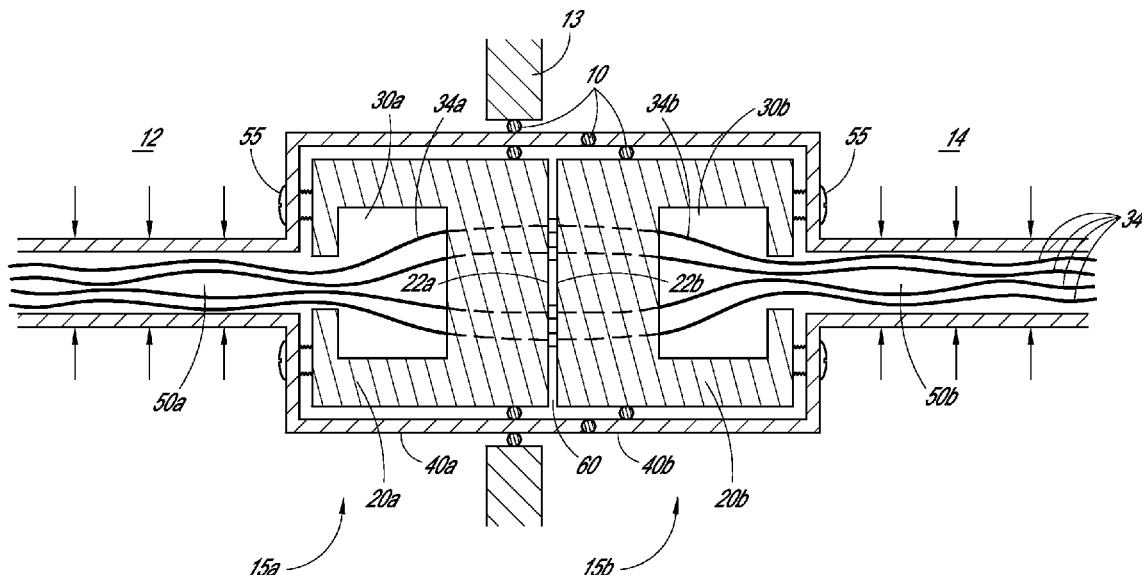
(57) **ABSTRACT**

(52) **U.S. Cl.**  
CPC ..... **G02B 6/3816** (2013.01); **G02B 6/3878** (2013.01); **G02B 6/3821** (2013.01); **G02B 6/3894** (2013.01)

This disclosure provides systems, methods, and devices for connecting optical fibers. In one aspect, a connector includes a transfer tube for equalizing the pressure between two chambers within the two connectors when the connectors are mated. The chambers may house biasing elements coupled to optical fiber holders to provide a pressure independent force against optical fiber terminals. The optical fiber holders may include side openings for receiving optical fibers.

(58) **Field of Classification Search**  
CPC ..... G02B 6/3816  
USPC ..... 385/59, 78  
See application file for complete search history.

**18 Claims, 12 Drawing Sheets**



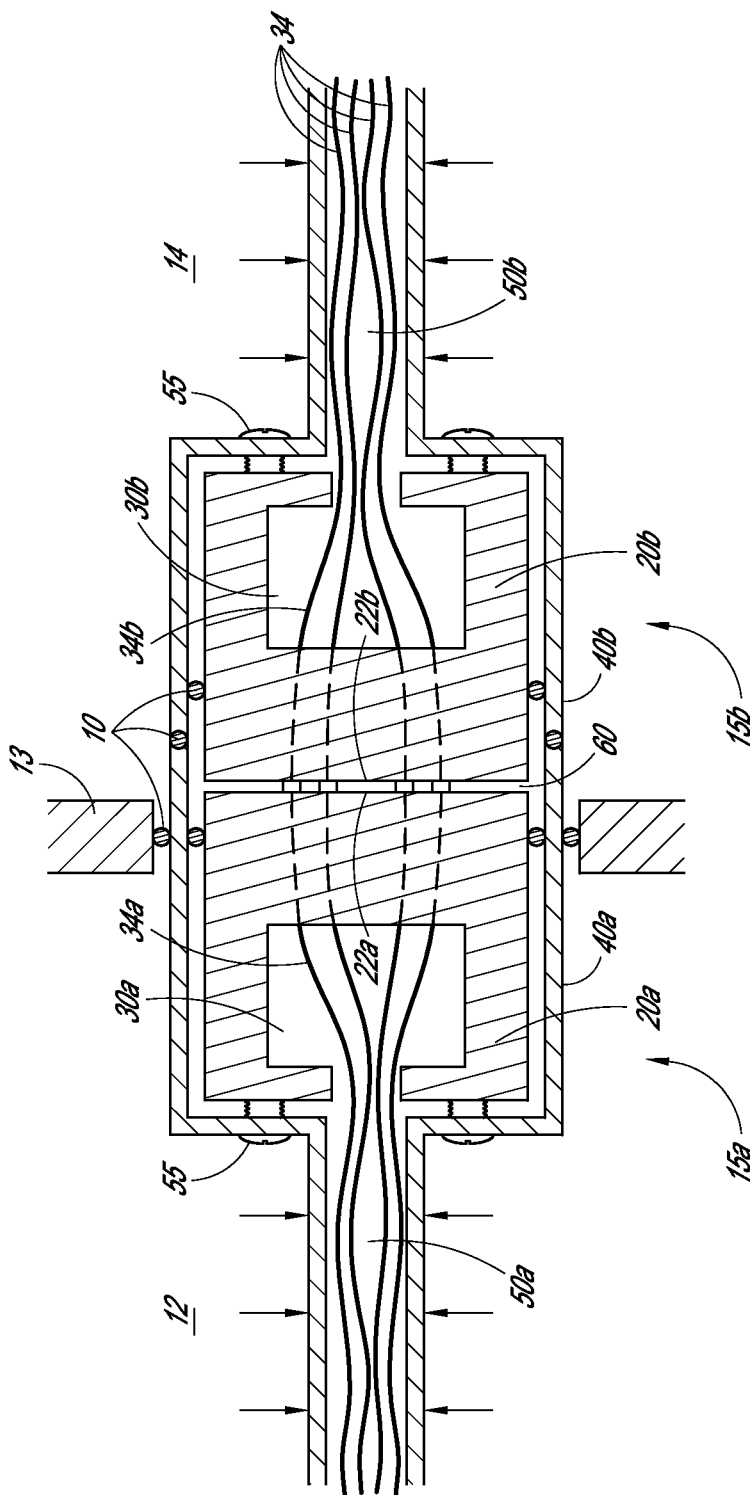


FIG. 1

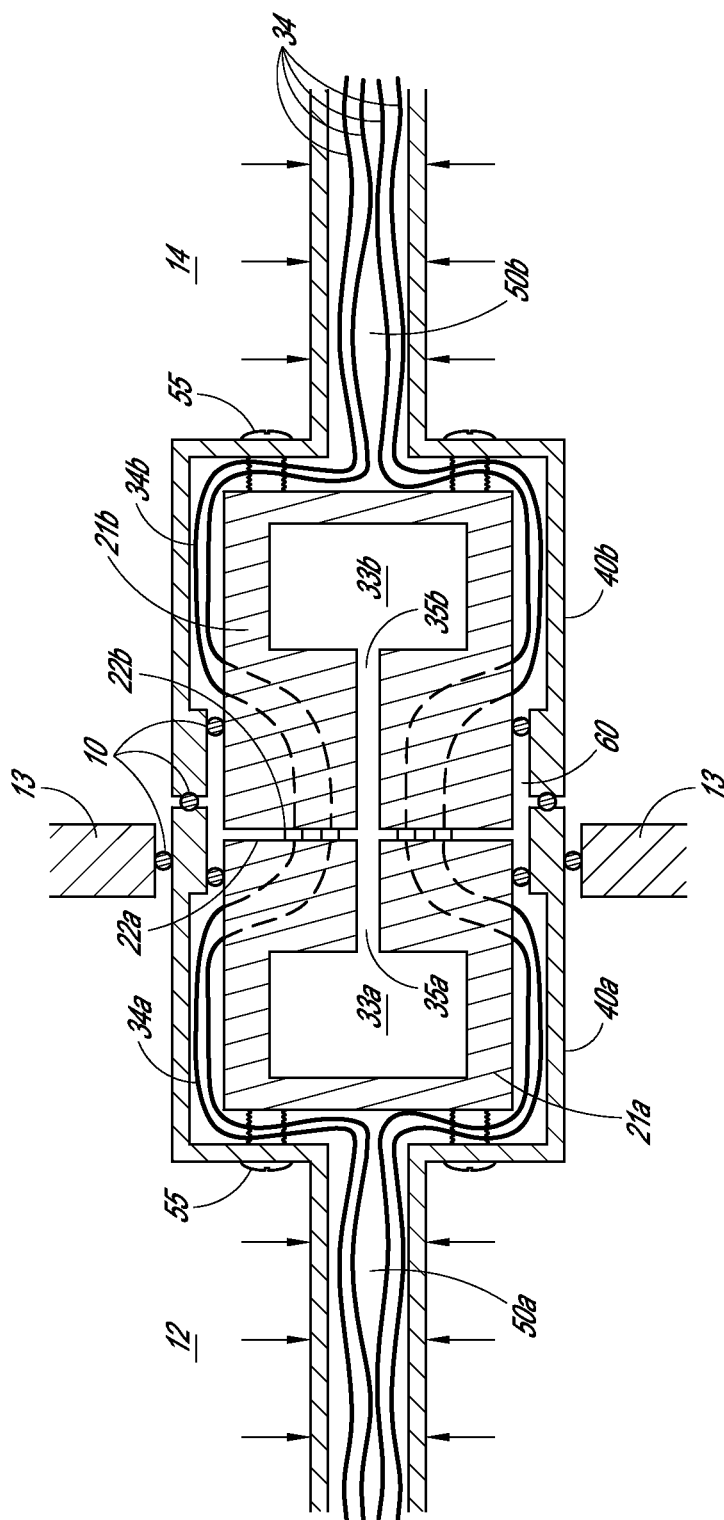


FIG. 2

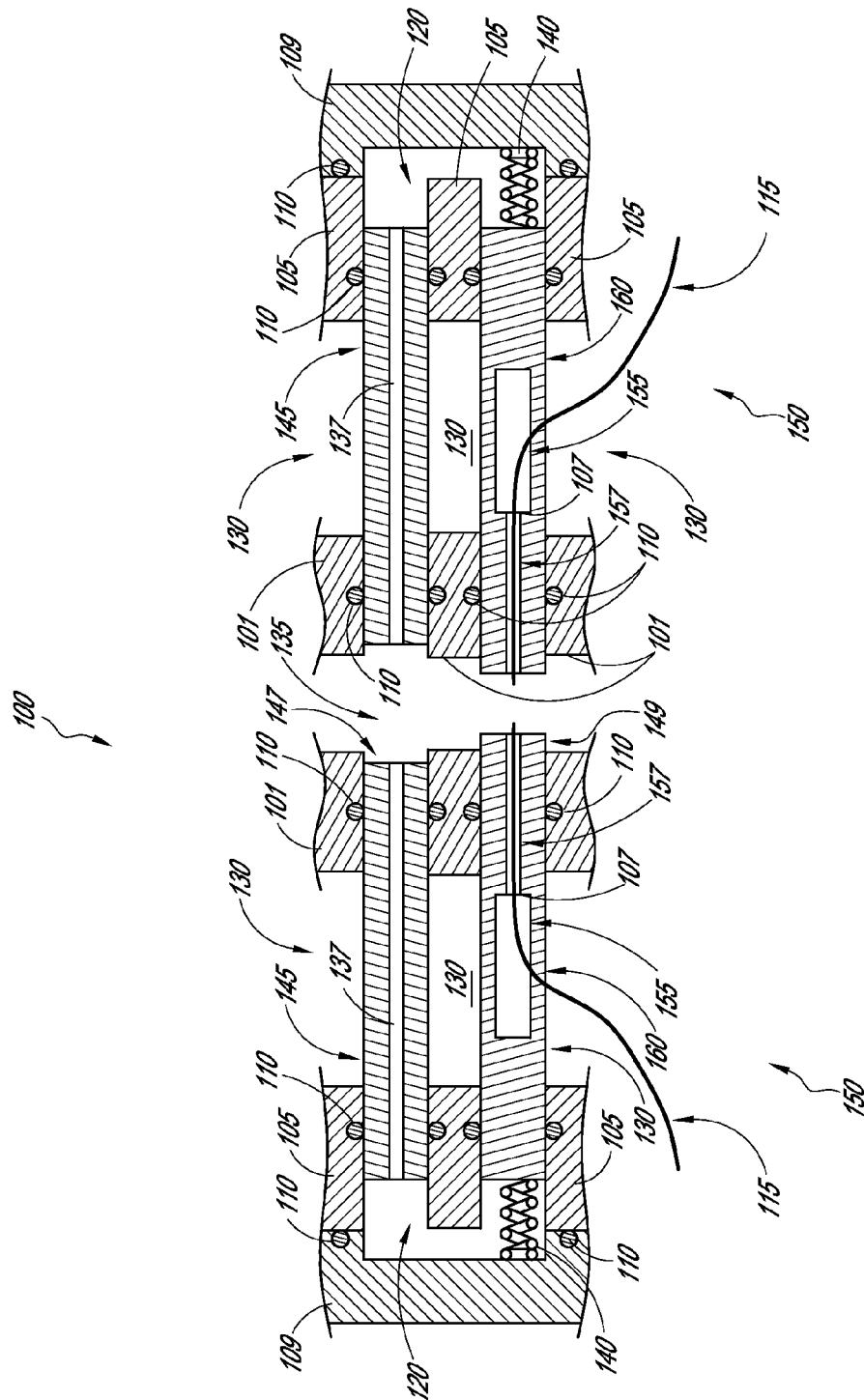


FIG. 3

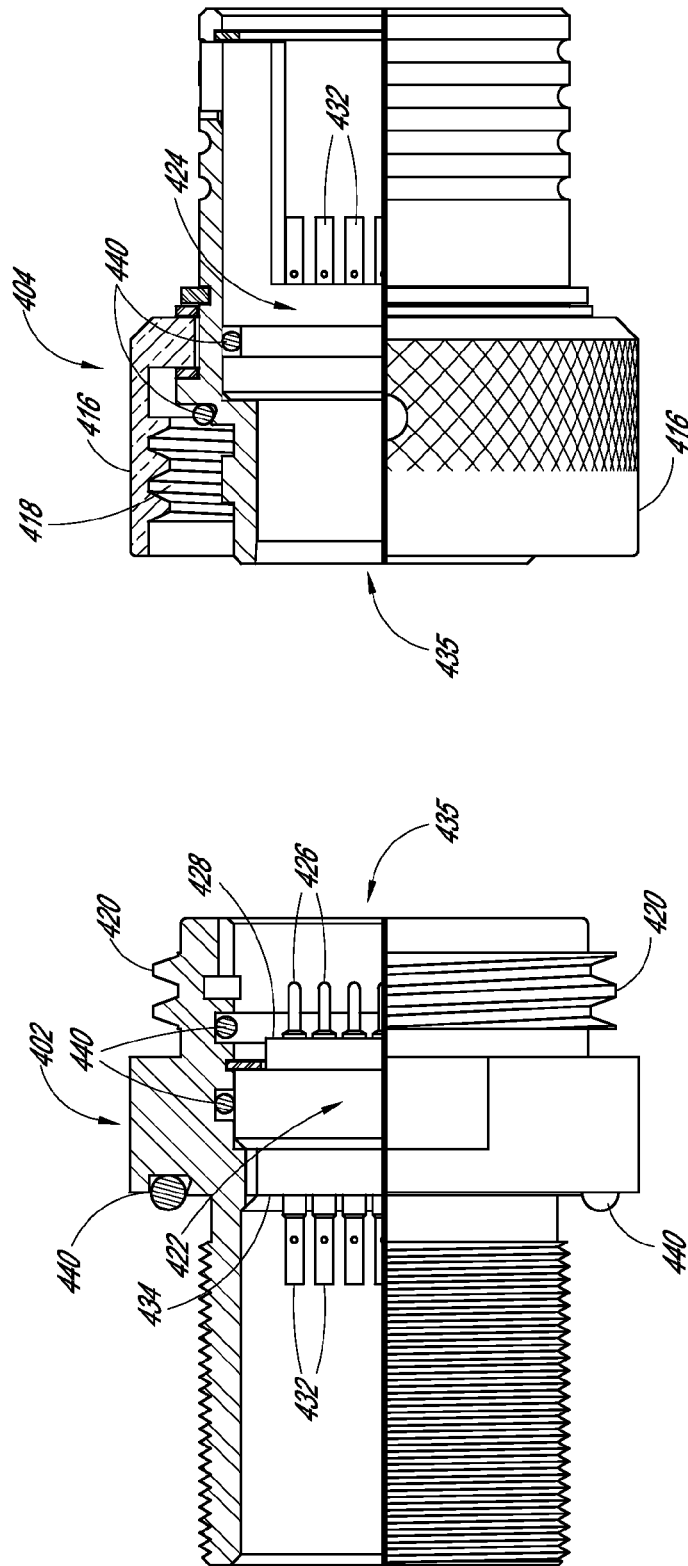
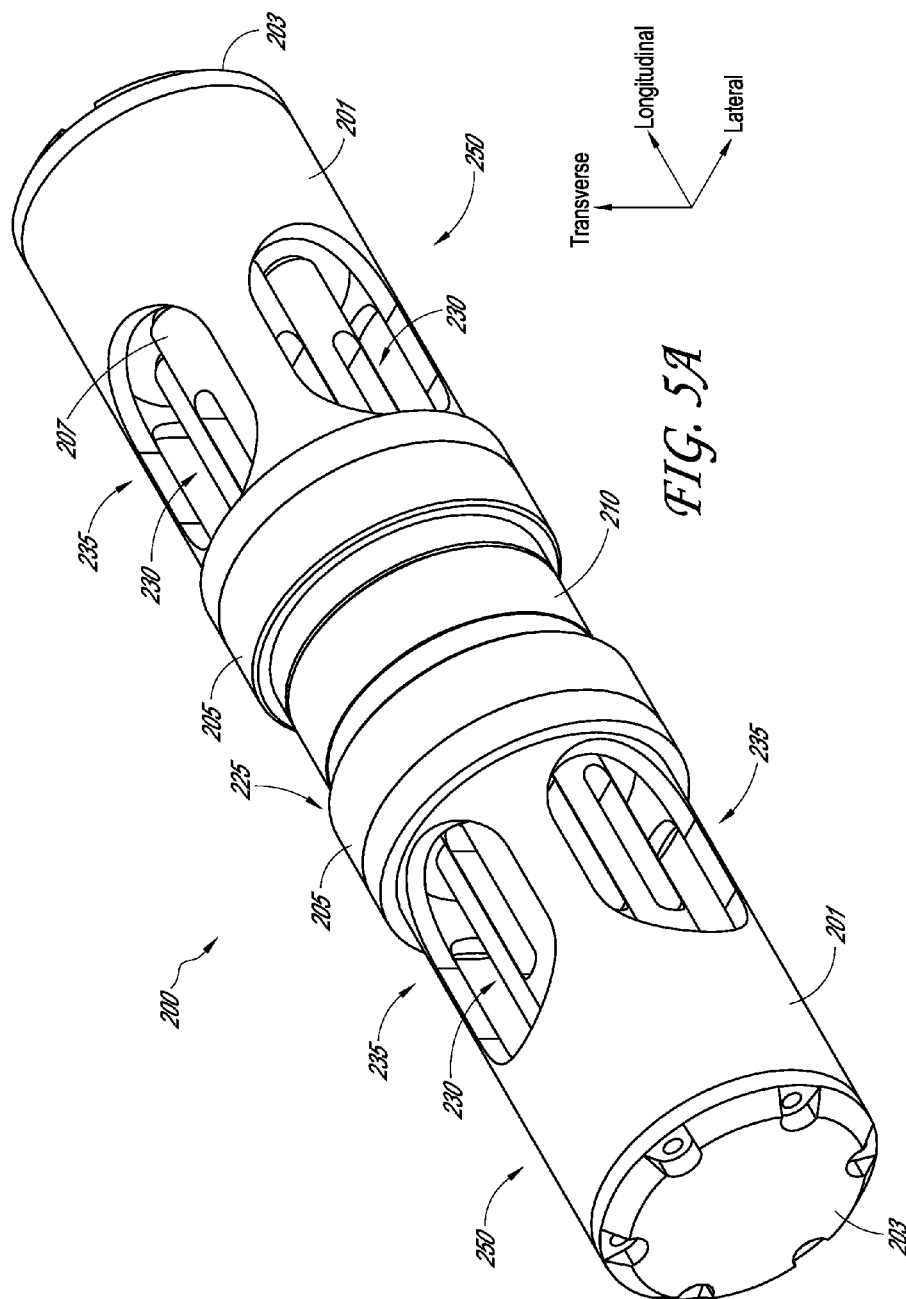


FIG. 4



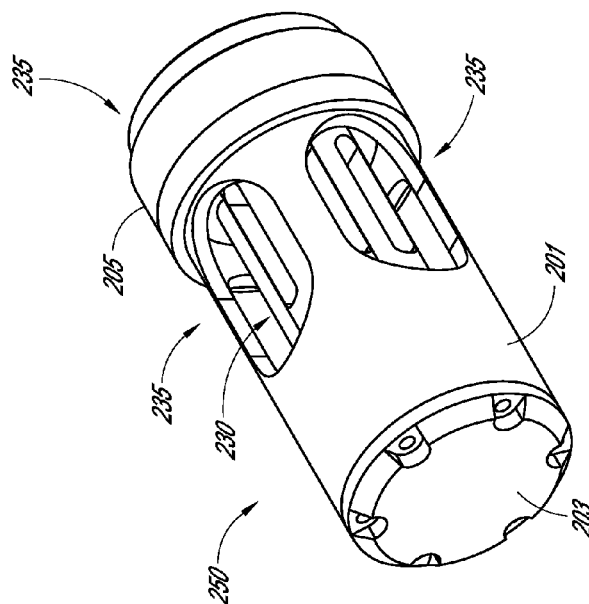
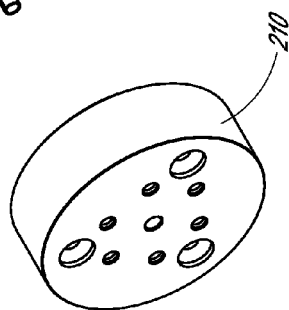
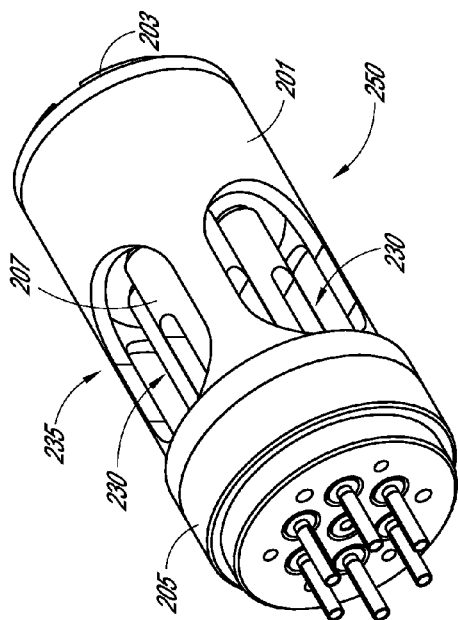
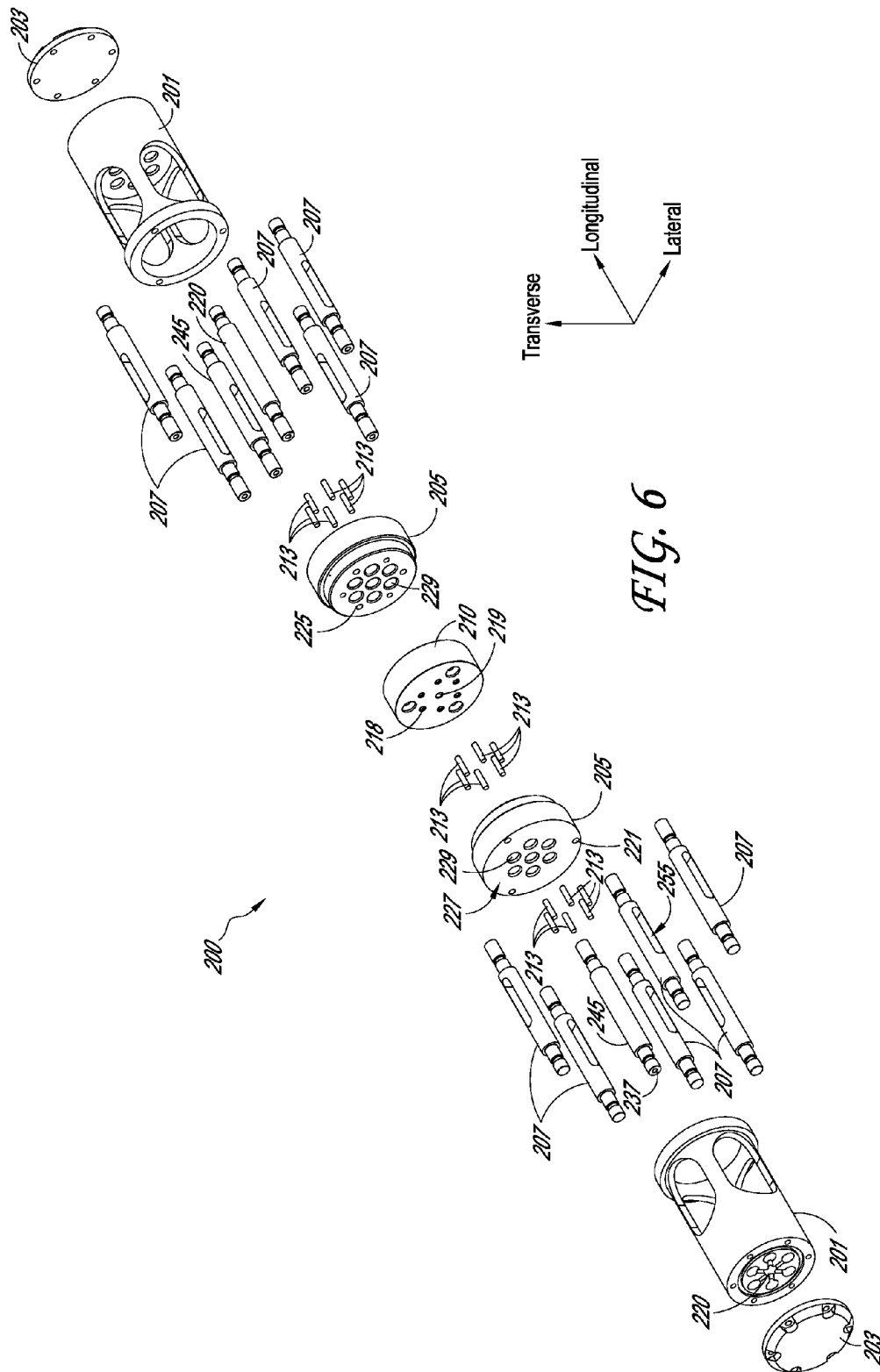
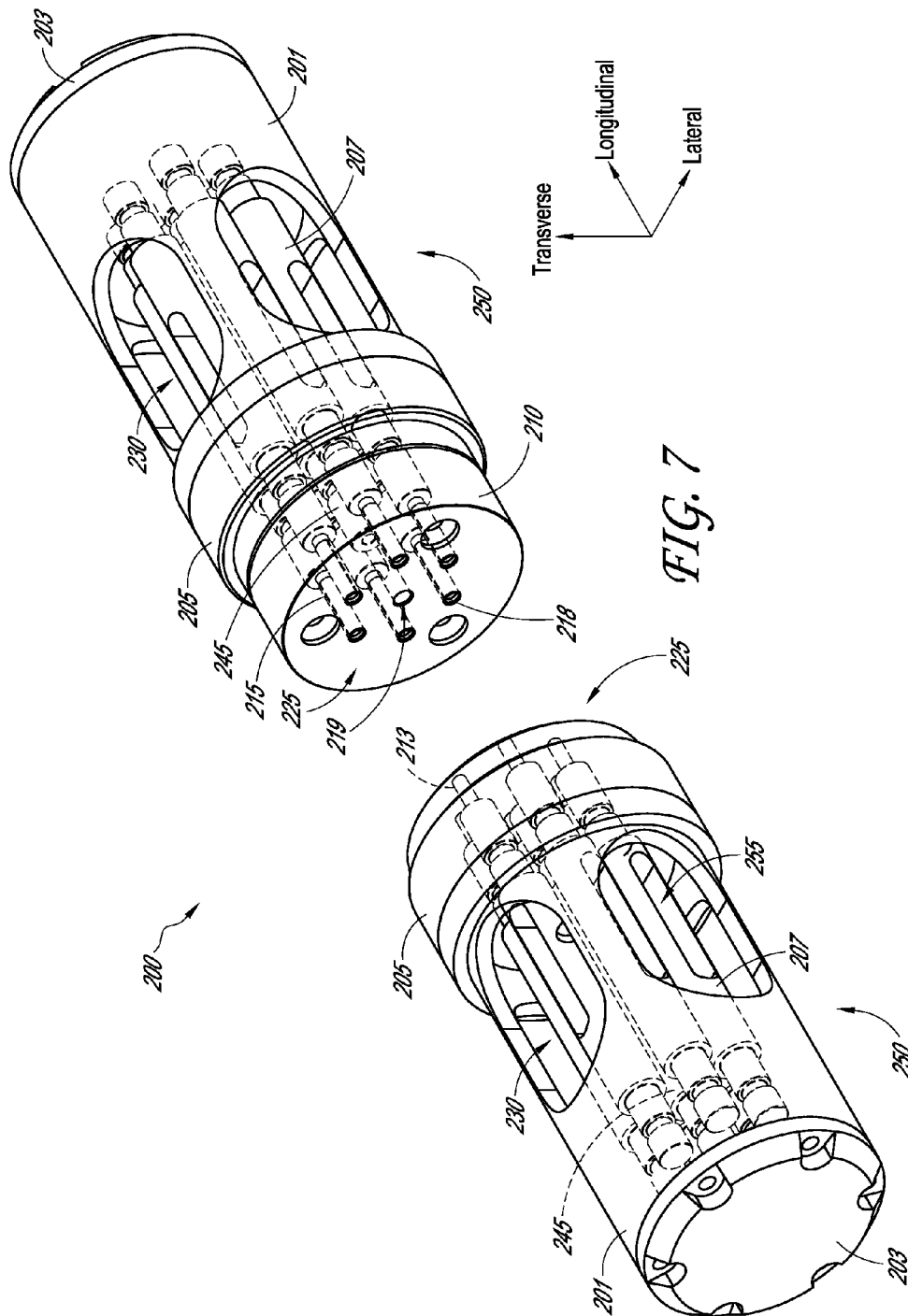
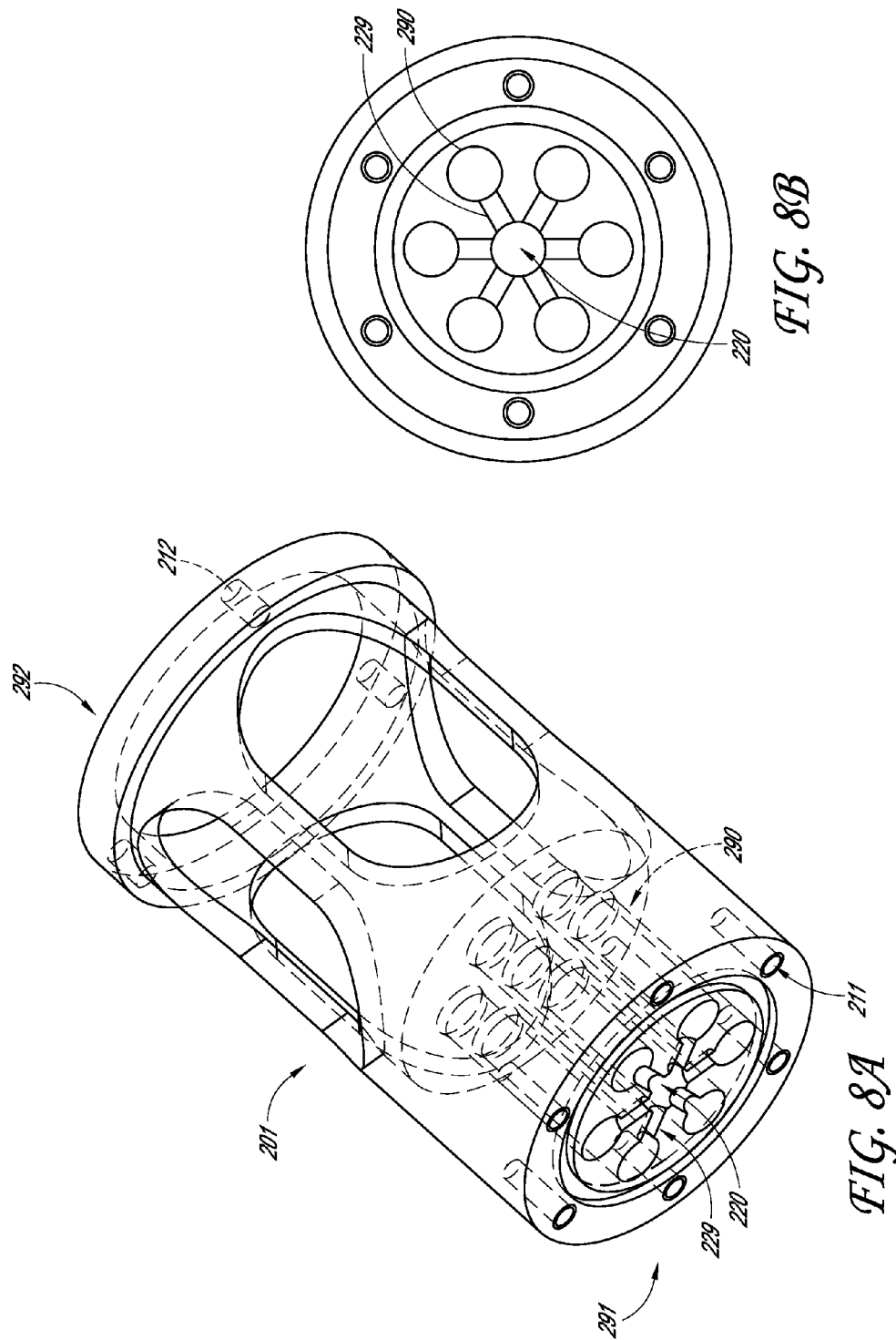


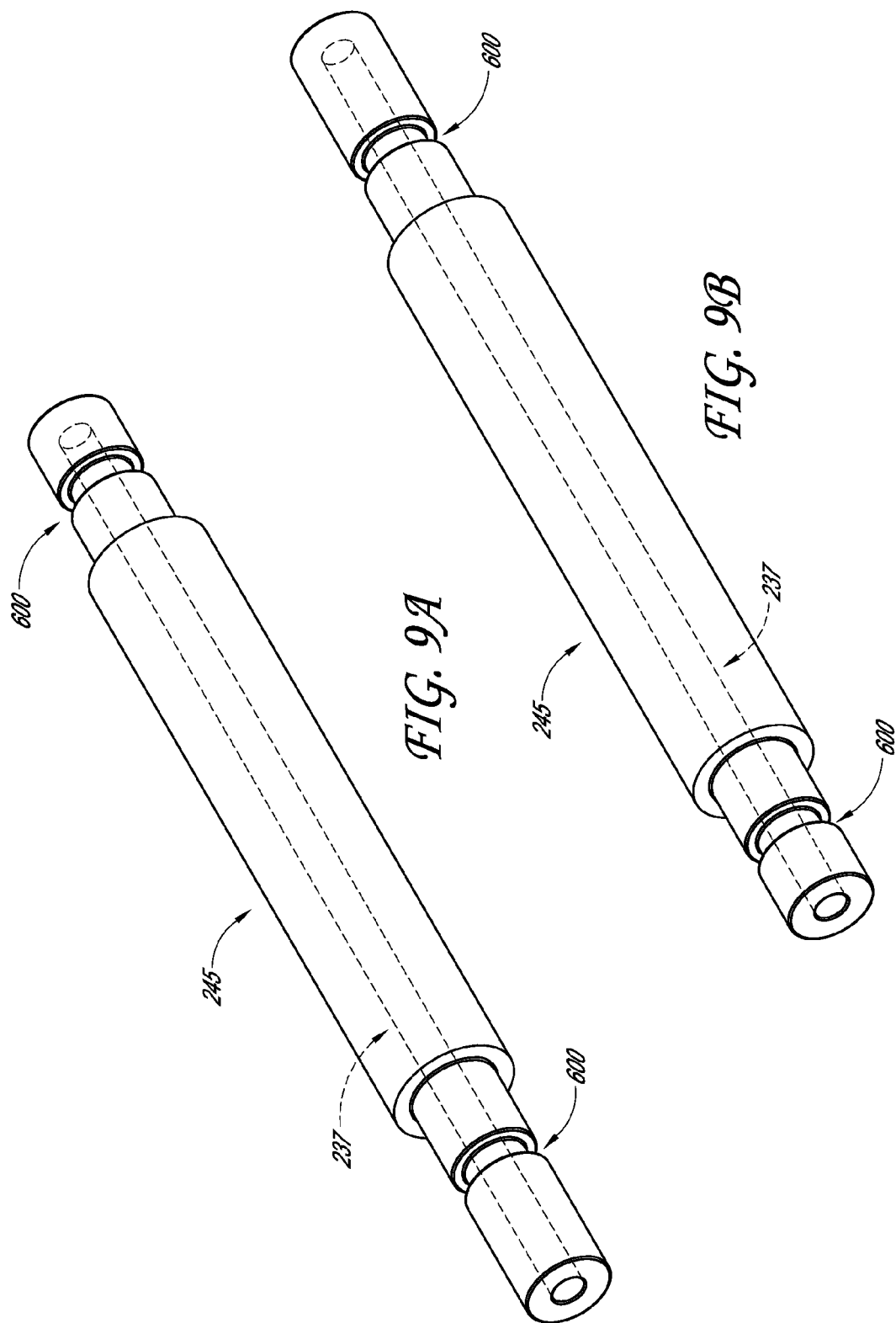
FIG. 5B

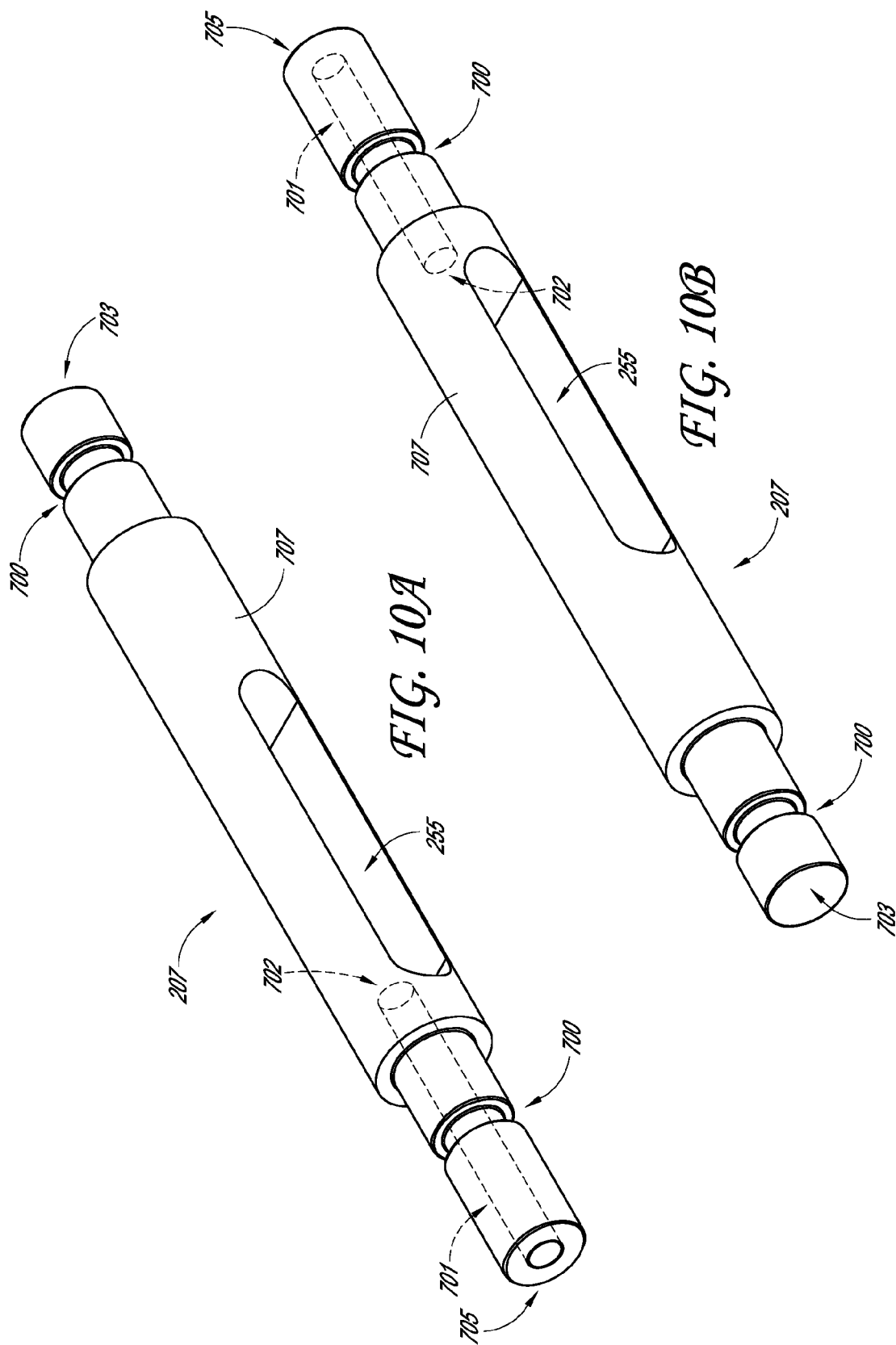












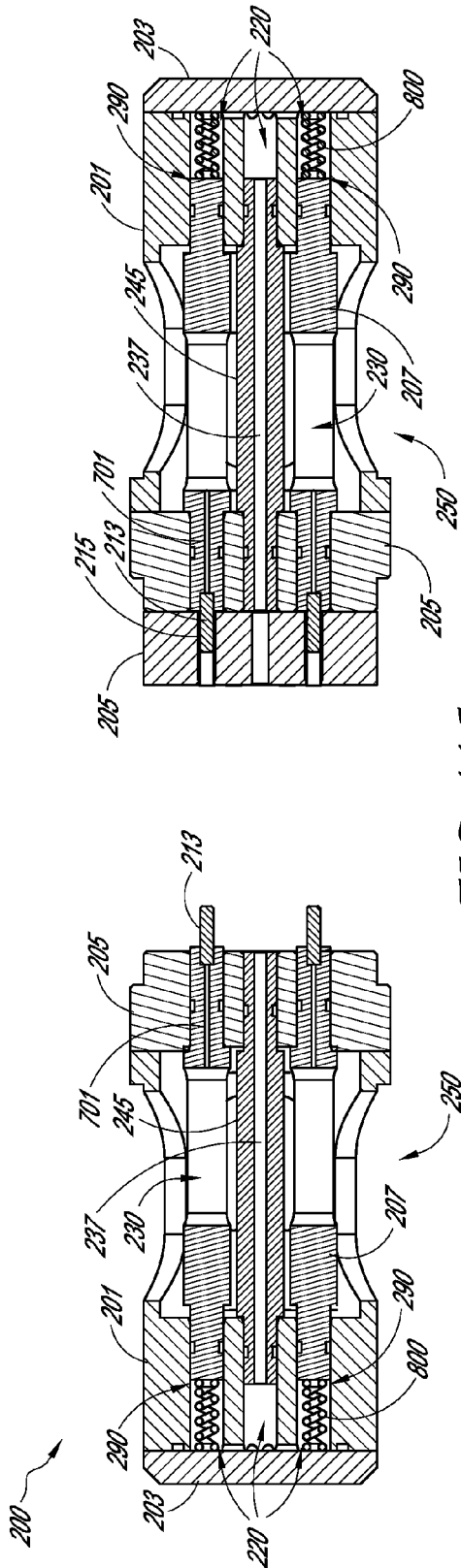


FIG. 11A

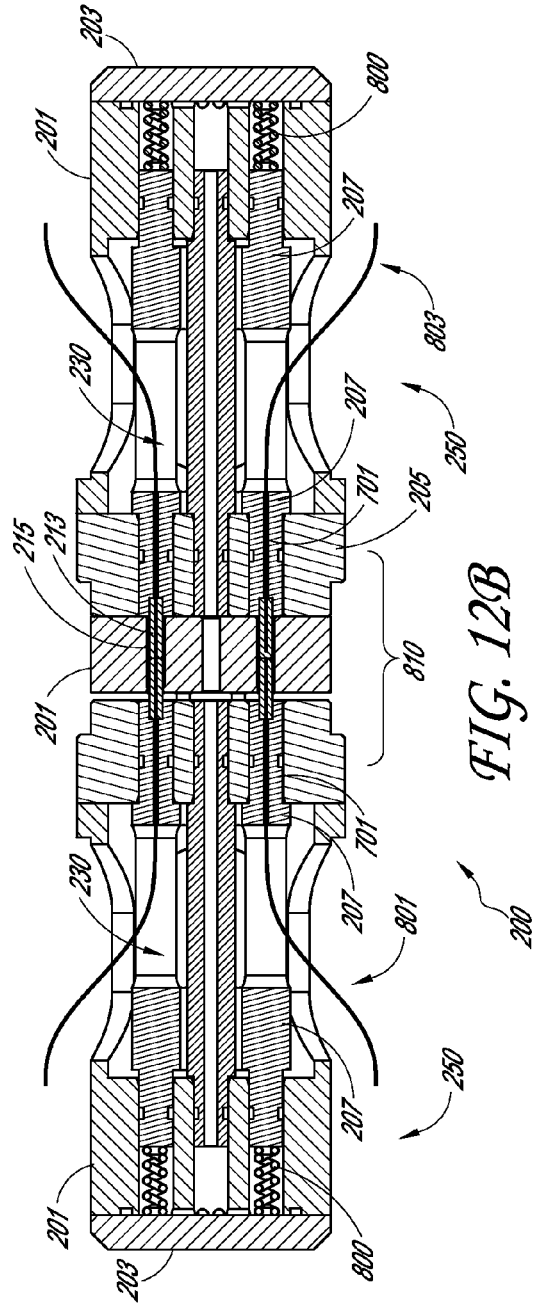


FIG. 12B

## 1

## CONNECTOR

INCORPORATION BY REFERENCE TO ANY  
PRIORITY APPLICATIONS

Any and all applications for which a domestic priority claim is made is identified in the Application Data Sheet as filed with the present application and is hereby incorporated by reference under 37 C.F.R. §1.57. This application is a continuation of U.S. patent application No. 13/949,075, filed on 23 Jul. 2013.

## BACKGROUND

## 1. Field

The inventions disclosed herein relate generally to the field of connectors and more specifically to fiber-optic and/or electrical connectors for use in deep sea applications.

## 2. Description of the Related Art

Underwater connectors are used extensively in ocean related applications including, for example, military submarines, research submarines, ocean science observatories, towed arrays, drilling systems, production control systems, remotely operated vehicles ("ROVS"), other mobile vehicle applications, underwater research and exploration activities, ocean mining, and offshore oil production.

In the design of underwater deep-sea connectors, several environmental parameters must be considered. A serious consideration is the exposure to extremely high water pressure at great ocean operating depths. These pressures can crush or otherwise deform connectors that are not properly designed to withstand such pressure. High pressure and water tight seals may also be provided to prevent water ingress that may lead to short circuiting of electrical contacts and otherwise foul the connector components. Connector materials in contact with salt water experience corrosion processes as well. At very great depths below the surface of the sea, the temperature of the seawater may approach freezing temperatures. Thus, connectors used in such environments will experience extreme external temperatures and pressures as well as hostile corrosive effects.

Many subsea electrical and optical cable and connection systems now utilize Pressure Balanced Oil Filled ("PBOF") cabling solutions. These cables utilize an elastomeric tube as a conduit for electric wires, copper conductors, and/or fiber optic lines. The elastomeric conduit is filled with a compensating fluid, allowing the sea pressure to freely communicate with the interior oil volume, equalizing the pressure in the assembly. This equalized differential pressure eliminates any motive force for seawater introduction resulting in sustained performance and operating lifetimes. Thus, PBOF cabling provides for a reliable and configurable cable system suitable for many subsea applications.

## SUMMARY

The devices, systems, and methods disclosed herein have several features, no single one of which is solely responsible for its desirable attributes. Without limiting the scope as expressed by the claims that follow, its more prominent features will now be discussed briefly. After considering this discussion, and particularly after reading the section entitled "Detailed Description" one will understand how the features of the system and methods provide several advantages over traditional systems and methods.

The subject matter disclosed herein relates to an underwater fiber optic connector. The connector includes a transfer

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tube for equalizing the pressure between two connectors when the two connectors are coupled together. In addition, the connector may include spring loaded optical fiber holders within the connector having side openings therein for the passage of optical fibers. The configurations disclosed below allow for a connection that is less susceptible to failure from pressure differences that cause forces to act on the fiber optic contacts.

One innovative aspect of the subject matter described in this disclosure is a connector that may comprise a connection face, a chamber, and at least one optical fiber holder, having a first end positioned within at least a portion of an opening in the connection face and a second end positioned within at least a portion of the chamber, the at least one optical fiber holder having an opening in a side surface for receiving an optical fiber. At least one biasing element may be positioned within the chamber and the biasing element may be configured to bias the optical fiber holder toward the connection face. At least one passageway may lead from the chamber to the connection face and the passageway may provide a pressure communication link between the connection face and the chamber. In some aspects, the pressure communication link comprises a conduit connecting the connection face and the chamber. In some aspects, the pressure communication link comprises an ambient airway passage. As used herein, the term fluid includes both liquids and gasses. The optical fiber holder may be longitudinally movable between a first position when the connector is not connected with another connector and a second position when the connector is connected with another connector. The passageway may comprise a lumen extending through a tube having a first end positioned within at least a portion of an opening in the connection face and a second end positioned within at least a portion of the chamber.

Another innovative aspect of the subject matter described in this disclosure is a connection system that may comprise a first connector insert having a connection face and chamber in pressure communication with the connection face, a second connector insert having a connection face and chamber in pressure communication with the connection face, at least one optical fiber holder having a first end at least partially positioned within an opening in the connection face of the first connector insert and a second end coupled to a biasing element positioned within the chamber of the first connector insert; and an outer shell configured to enclose the connection face of the first connector and the connection face of the second connector to form a pressure tight enclosure with the chambers in pressure communication through the connection faces. The optical fiber holder may include an opening in a lateral or transverse surface of the optical fiber holder for insertion of an optical fiber.

Another innovative aspect of the subject matter described in this disclosure is a connector that may comprise a connection face, a chamber, and at least one optical fiber holder having a first end positioned within at least a portion of an opening in the connection face and a second end at positioned within at least a portion of the chamber, at least one biasing element configured to bias the optical fiber holder toward the connection face, and a means for preventing a pressure dependent force from acting on the second end of the at least one optical fiber holder. The means for preventing a pressure dependent force may comprise a pressure communication link between the chamber and the connection face and an opening in a lateral or transverse surface of the optical fiber holder for insertion of an optical fiber.

Another innovative aspect of the subject matter described in this disclosure is a deep sea underwater connector for

connecting angled fiber optic terminals that may comprise a connector shell, an insert disposed within the connector shell having an end cap coupled to one end and a connection cap coupled to the opposite end, the connection cap having a rear face at a first pressure and a connection face at a second pressure, a sealed chamber disposed within the insert chamber, the sealed chamber configured to be at substantially the second pressure, a biasing element disposed within the rear chamber, at least one fiber optic holder having a rear end at least partially disposed in the rear chamber and coupled to the biasing element, and a connection end at least partially disposed within the connection cap, and a passageway for a fiber optic line disposed within the fiber optic holder extending from a first opening in the connection end to a second opening positioned between the connection end and the rear chamber.

These and other features, aspects, and advantages of the invention disclosed herein are described below with reference to the drawings of certain embodiments of the present invention.

### BRIEF DESCRIPTION OF THE DRAWINGS

The illustrated embodiments of the connection system and components are intended to illustrate but not to limit the invention. Additionally, from figure to figure, the same reference numerals have been used to designate the same components of an illustrated embodiment. The following is a brief description of each of the drawings.

FIG. 1 is a schematic cross-sectional view of a conventional connection system.

FIG. 2 is a schematic cross-sectional view of a connection system according to one embodiment.

FIG. 3 is a schematic cross-sectional view of a connector system according to another embodiment.

FIG. 4 is a side and partially cut away view of an example connector shell having connector inserts.

FIG. 5A is a perspective view of a connector system according to another embodiment.

FIG. 5B is a partial exploded perspective view of the connector system of FIG. 5A.

FIG. 6 is an exploded perspective view of the connector system of FIGS. 5A-5B.

FIG. 7 is perspective view of the connector system of FIGS. 5A-5B illustrating the positioning of internal optical contact bodies and equalizer tube within the connector system.

FIG. 8A is a transparent perspective view of the connector insert of the connector system of FIGS. 5A-5B.

FIG. 8B is a bottom view of the connector insert of FIG. 8A.

FIGS. 9A-9B are perspective views of an equalizer body of the of the connector system of FIGS. 5A-5B.

FIGS. 10A-10B are perspective views of an optical contact body of the of the connector system of FIGS. 5A-5B.

FIG. 11A is a cross-sectional view of the connector system of FIGS. 5A-5B.

FIG. 12B is a cross-sectional view of the connector system of FIGS. 5A-5B when coupled together and including a fiber optic connection.

### DETAILED DESCRIPTION

The following description and the accompanying figures describe and show various embodiments and are made to demonstrate several possible configurations that a connection can take to include various disclosed aspects and features. The illustration of the connector systems and components in this context is not intended to limit the disclosed aspects and

features to the specified embodiment or to any particular usage. Those of skill in the art will recognize that the disclosed aspects and features are not limited to any particular embodiment of a connector, which include one or more of the inventive aspects and features herein described, and can be designed for use in a variety of applications. It is noted that the figures provided herein may not be drawn to any particular proportion or scale, and that many variations can be made to the illustrated embodiments.

As used herein, the singular forms "a," "an," and "the" include both singular and plural referents unless the context clearly dictates otherwise. The terms "comprising," "comprises" and "comprised of" as used herein are synonymous with "including," "includes" or "containing," "contains," and are inclusive of open-ended and do not exclude additional, non-recited members, elements or method steps. The terms "comprising," "comprises," and "comprised of" when referring to recite components, elements or method steps also include embodiments which "consist of" said recited components, elements or method steps. Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order, unless specified. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner, as would be apparent to a person skilled in the art from this disclosure, in one or more embodiments. Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those in the art. For example, in the appended claims, any of the features of the claimed embodiments can be used in any combination.

Optical fibers are frequently used for communicating with deep underwater submersibles. For example, it is often necessary to connect a fiber optic cable to a submersible in a dry environment using a fiber optic connector and then to submerge the submersible to great ocean depths. Thus, the fiber optic connector must be able to withstand high pressures (for example, a pressure greater than 4,000 psi). The fiber optic connector must also precisely align and press together multiple fiber optic contacts such that light may be transmitted efficiently therethrough. In addition, many deep underwater submersibles include external fiber optic lines connecting various components of the submersible. Such external fiber optic lines may comprise PBOF cables.

The connection devices described herein are especially adapted to join two PBOF cables containing one or more electrical and/or fiber optic lines together. The connection devices described herein are also adapted to join a PBOF cables containing one or more electrical and/or fiber optic lines to a submersible. The connectors are configured such that there is an approximately constant contact force between

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two fiber optic lines with their faces mated together and/or configured such that there is an approximately constant contact force between a connection at end of a fiber optic line and a bulkhead connection. This is advantageous because pressure imbalances can cause one optical fiber to be forced against another optical fiber at the junction between the two lines which can damage the optical line and/or optical connection. The connectors are also configured to have a long operating life in seawater and configured to withstand large pressures. Another advantage of some embodiments of the current disclosure is that two halves of a connector may be substantially the same, eliminating the need for a specialized male-female system.

In some applications, when a PBOF cable is coupled to a submersible, a pressure imbalance between the cable side of a connection and submersible side of the connection is created because a portion of the PBOF cable outside of the submersible may be at a first pressure that is substantially the same as the pressure outside of the submersible while a portion of the cable inside the submersible may be at a second pressure substantially the same as the pressure inside the submersible. Often the pressure outside of the submersible is much greater than the pressure inside of the submersible. This pressure imbalance between two portions of one or more PBOF cables coupled together may impart forces on the optical fibers within the cables. A pressure imbalance may also be present when a PBOF cable is connected to a bulkhead of an underwater submersible. Such pressure imbalances may push the end face of one optical fiber against the end face another optical fiber at the interface between two optical fibers causing the optical fibers to fracture and/or become misaligned.

In some embodiments, the optical fibers include an angled polished contact ("APC") termination, or similar commonly known termination scheme. An APC termination typically utilizes a complimentary eight degree angled cut on the end of each of the fiber optic leads. It is desirable to ensure the two leads are correctly aligned, axially and angularly, such that of the angled ends of the leads are in complimentary contact with each other. Pressure imbalances can lead to forces at the interface of two complimentary APC ends that are mated in contact with one another. Such forces can cause the APC ends to move, leading to misalignment of the APC interface. Thus, the connection system disclosed herein advantageously reduces misalignment of APC ends by maintaining an approximately constant contact force at the interface between the two ends.

To assist in the description of the components of embodiments of the connection system, the following coordinate terms are used, consistent with the coordinate axes illustrated, for example, in FIG. 5A. A "longitudinal axis" extends generally lengthwise through the connectors 205 and is generally parallel to the generally cylindrical passageways running through the connectors 205. A "lateral axis" is normal to the longitudinal axis and is generally parallel to the plane of the front face of the connectors 205. A "transverse axis" extends normal to both the longitudinal and lateral axes. In addition, as used herein, the "longitudinal direction" refers to a direction substantially parallel to the longitudinal axis; the "lateral direction" refers to a direction substantially parallel to the lateral axis; and "the transverse direction" refers to a direction substantially parallel to the transverse axis.

FIG. 1 is a schematic cross-sectional view of a conventional connection system. The conventional connection system illustrates the interior of a submersible 12 and an exterior of a submersible 14 separated by a pressure sealed (with seals 10 in FIG. 1) partition 13. The interior of the submersible 12

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may be at a first pressure and the exterior of the submersible 14 may be at a second pressure. When the submersible is deployed to great ocean depths, the pressure difference between the interior of the submersible 12 and the exterior of the submersible 14 may be large. An exterior portion of a PBOF cable 50b is coupled to an exterior connector 15b while an interior portion of a PBOF cable 50a is coupled to an interior connector 15a and/or bulkhead. The PBOF cables include a plurality of optical fibers 34. As discussed above, the pressure difference between the exterior portion of the PBOF cable 50b and the interior portion of the PBOF cable 50a may also be large.

The connectors 15a and 15b include two connector inserts 20a and 20b substantially surrounded by two connector shells 40a and 40b. One or more fasteners 55 may secure the connector insert 20a and 20b to the connector shell 40a and 40b. Thus, the connector insert 20a and 20b may be prevented from moving relative to the connector shell 40a and 40b. The connector inserts 20a and 20b include connection faces 22a and 22b. When the two connector shells 40a and 40b are coupled together in a pressure sealed manner, a central chamber 60 is formed. Seals 10 are configured to prevent liquid and/or gas from entering or exiting the central chamber 60. Chambers 30a and 30b positioned behind the connection faces 22a and 22b are in pressure communication with the PBOF cables 50a and 50b. The optical fibers 34 may pass through the connection faces 22a and 22b and various techniques can be used to ensure that fluid and/or gas does not pass through the connection face and into or out of the central chamber 60. Furthermore, various biasing mechanisms may be employed to provide a biasing force against an optical fiber that exits the connection face. For instance, a spring may be disposed in the chamber 30 that abuts a rear surface of an optical contact tube.

Continuing with FIG. 1, a first optical fiber 34a passes through the interior PBOF cable 50a and into the chamber 30a of connector 15a. The first optical fiber 34a then passes through the connection face 22a and at least the terminal end of the first optical fiber 34a extends into the central chamber 60. A second optical fiber 34b passes through the exterior PBOF cable 50b and into the chamber 30b of connector 15b. The second optical fiber 34b then passes through the connection face 22b and at least the terminal end of the first optical fiber 34b extends into the central chamber 60 and is mated with the terminal end of the first optical fiber 34a. As discussed above, in the connection system shown in FIG. 1, a pressure imbalance between, for example, chamber 30a and central chamber 60 may cause a force against the optical fibers that pass through the connector insert 30a.

Turning to FIG. 2, a schematic cross-sectional view of a connection system according to one embodiment is illustrated. FIG. 2 is similar to FIG. 1. However, in the embodiment shown in FIG. 2, the optical fibers enter through the sides of the connector inserts 21a and 21b. Thus, the impact of pressure dependent forces acting against the portion of the optical fibers passing through the connector insert is reduced. In addition, the connector inserts 21a and 21b include chambers 33a and 33b that are in pressure communication with each other and the central chamber 60 via passageways 35a and 35b. The chambers 33a and 33b may house biasing members that can provide an approximately constant force against the optical fibers that is independent of any pressure differences in the respective PBOF cables 50a and 50b as will be further explained below.

With reference now to FIG. 3, a connection system 100 according to one embodiment is illustrated. The connection system 100 includes two connectors 150. The connectors 150



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are configured to be coupled and secured together such that the interface area **135** between the two connectors **150** is pressure sealed. The connectors **150** can be secured together such that liquid and/or gas may not enter or exit the interface area **135** between the connection faces of two connectors **150**. The connectors **150** can be coupled together by any technique known in the art. For example, the connectors **150** may be surrounded by an outer shell that has a snap together or screw together connection. One or more seals may be included between such an outer shell and the connectors **150** to ensure a pressure tight connection.

Continuing with FIG. 3, each connector **150** may include a front cap **101** and a rear cap **109** sealingly secured to an insert **105**. The rear cap **109** and insert **105** can form a chamber **120**. In order to sealingly secure the rear cap **109** to the insert **105**, a seal **110** may be included between the cap **109** and the insert **105**. The interior **130** of the insert **150** behind the front cap **101** and in front of the chamber **120** may be in pressure communication with a PBOF cable. The front cap **101** is further configured such that liquid or gas from the interior of the connector **130** cannot enter the interface **135** between the connection sides of two connectors **150**.

The chamber **120** is in pressure communication with the interface area **135** between the two connectors **150**. In this way, the chamber **120** will have the same internal pressure as the pressure at the interface **135** between the two connectors **150**. In addition, when two connectors **150** are coupled together, the pressure in both chambers **120** of both connectors **150** will be at the same pressure because the two chambers **120** are both in pressure communication with the interface area **135**. In general, pressure communication may be established by providing a passageway in fluid and/or gaseous communication between the connection face and the chamber. The pressure communication link may comprise an ambient airway passage. Thus, when a connector disclosed herein is coupled to another connector or similarly constructed bulkhead above water, the connection face and rear chamber are both at ambient pressure. In other embodiments, the rear chamber comprises a sealed chamber that has an ambient internal pressure. Thus, a fluid and/or gaseous communication between the connection face and the chamber may not be required.

In the illustrated embodiment of FIG. 3, an equalizer tube **145** is used to provide such a pressure communication with the interface area **135** between the connectors **150** and the chambers **120**. As shown, one end of the equalizer tube **145** is disposed at least partially within the chamber **120** and the other end of the equalizer tube **145** is disposed at least partially within an opening **147** in the front cap **101**. The equalizer tube **145** may include at least one lumen **137** extending therethrough such that air or gas may pass to and from the chamber **120**, through the lumen **137**, and into and out of the interface **135** between the two connectors **150**. A seal **110** may be positioned between the equalizer tube **145** and the opening in the chamber **120** that the equalizer tube **145** passes through. Another seal **110** may be positioned between the equalizer tube **145** and the opening in the front cap **101** that the equalizer tube **145** passes through. In this way, liquid and/or gas may not pass from the interior region **130** of the connector into the chamber **120** or into the interface **135** between two connectors.

With continued reference to FIG. 3, each connector **150** includes an optical fiber holder **160**. As shown, one end of the optical fiber holder **160** is disposed at least partially within the chamber **120** and the other end of the optical fiber holder **160** is disposed at least partially within an opening **149** in the front cap **101**. A seal **110** may be positioned between the optical

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fiber holder **160** and the opening in the chamber **120** that the optical fiber holder **160** passes through. Another seal **110** may be positioned between the optical fiber holder **160** and the opening in the front cap **101** that the optical fiber holder **160** passes through. In this way, liquid and/or gas may not pass from the interior of the connector **130** into the chamber **120** or into the interface **135** between two connectors **150**.

As shown in FIG. 3, the optical fiber holder **160** is coupled to a wall of the chamber **120** with a contact spring **140**. The contact spring **140** provides a force that pushes the contact tubes **160** towards each other when the connectors **150** are mated. The contact spring **140** provides a biasing force on the optical fiber holder **160** and the optical fiber holder **160** can move into the chamber **120** and compress the contact spring **140** when a force is applied to the end of the optical fiber holder **160** opposite to the contact spring **140** during connector mating.

The optical fiber holder **160** includes a window **155** and a lumen **157** extending from the window **155** to the interface **135** between the connectors **150**. An optical fiber **115** may be positioned such that the optical fiber **115** passes from the interior region **130** of a connector **150** and into the optical fiber holder **160** through the window **155**, into and through the lumen **157**, and into the interface **135** between the connectors. A seal **107** may be used to prevent liquid and or gas from passing from the interior **130** of the connector and into the interface **135** between the connectors **150**. The seal **107** may comprise epoxy that fills at least a portion of the window **155** and/or lumen **157**. The optical fiber **115** may be housed within a ferrule disposed within the optical fiber holder **160**.

When the two connectors **150** are coupled together, the contact springs **140** provide a force that presses the contact tubes **160** together. In this way, the optical fibers **115** within the optical fiber holders **160** are also pressed together ensuring a tight connection between the optical fibers **115**. Furthermore, because the contact springs **140** are located within the chambers **120**, and the chambers **120** are at the same pressure because of the transfer tubes **145**, there is no pressure difference between the chambers **120** and the only force on the optical fiber holders **160** is the force provided by the contact springs **140**. Thus, while the pressure in the interior region **130** of one connector **150** may be greater than the pressure in the interior region **130** of the other connector **150**, this pressure difference does not affect the force with which the contact tubes **160** are pressed against each other. Thus, the connectors **150** are configured to provide an external pressure independent contact force between two optical fibers **115** mated together. This configuration greatly reduces the risk of the optical fibers becoming damaged and/or misaligned.

With brief reference to FIG. 4, a side and partially cut away view of an example connector shell having connector inserts is illustrated. The pair of connector shells **402** and **404** are configured to be coupled together in a pressure tight and/or water tight manner. The connector shells **402** and **404** contain insert bodies **422** and **424**. The connector shells **402** and **404** may be coupled together using an engagement nut **416** having internal screw threads **418** that engage with external screw threads **420**. The connection side faces **435** of the insert bodies may be enclosed in a sealed environment when the connector shells are coupled together. Insert body **422** may include a plurality of contact pins or ferules that project from the front face **428** of the insert body **422**. The rear face **434** of the insert body **422** may include a plurality of contact receiving projections **432** for connection to wire leads and/or fiber optic lines. A plurality of seals **440**, O-rings for example, may be included to ensure a pressure tight and/or water right seal when the connector shells **402** and **404** are coupled together.

Seals also provide a pressure tight and/or water tight seal that the rear face **434** of the insert body **422** is not in pressure and/or fluid communication with the front face **428** of the insert body **422**.

Turning now to FIGS. **5A-5B**, perspective views of a connector system **200** according to another embodiment are illustrated. Similar to the embodiment shown in FIG. **3**, the connector system **200** includes two connector inserts **250** having chambers configured to be in pressure connection with the interface area between the two connectors **250**. In this way, when two connectors **250** are coupled together, the chambers will have the same internal pressure which will be the same as the pressure at the interface between the two connectors. Accordingly, the connector system **200** is configured to provide a pressure independent contact force between two fiber optic (or electronic) terminals mated together.

As shown in FIGS. **5A-5B**, the connector system **200** includes two connectors **250** and an alignment adaptor **210** therebetween. Each connector insert **250** includes an insert body **201** having a first end cap **203** secured to one end of the insert body **201** and a second end cap **205** secured to the other end of the insert body **201**.

The insert body **201** is generally cylindrically shaped and can be sized to mate with various sized PBOF cables as necessary. The insert body **201**, first end cap **203**, and second end cap **205** may be formed of swaged stainless steel, titanium, or other materials suitable for deep sea applications. As illustrated in FIG. **5B**, the insert body **201** includes four windows **235**. In this way, the interior **230** of the insert body **201** is in pressure communication with a cable secured about the insert body **201**. More or fewer windows **235** may be provided and the windows may be shaped and sized as desired.

The first end cap **203** is sealingly secured to one end of the insert body **201**. As shown, the first end cap **203** is secured to the insert body **201** by a plurality of fasteners such as screws. However, the first end cap **203** may be secured to the insert body **201** by other means such as a weld. One or more seal structure such as washers may be provided between the first end cap **203** and the insert body **201** to further ensure that liquid and/or gas may not ingress or egress between the first end cap **203** and insert body **201**. As will be described below, securing the first end cap **203** to the insert body **201** forms a chamber that is in pressure communication with the opposite end of the insert body **201**.

Second end cap **205** is sealingly secured to the end of the insert body **201** opposite to the end that includes a first end cap **203**. As shown, the second end cap **205** may be secured to the insert body **201** by a plurality of fasteners such as screws. However, the second end cap **205** may be secured to the insert body **201** by other means such as a weld. One or more seals may be provided between the second end cap **205** and the insert body **201** to further ensure that liquid may not ingress or egress between the interface of the second end cap **205** and the insert body **201**. As also shown, an alignment adaptor **210** may be positioned between two inserts **250**.

The insert body **201**, first end cap **203**, and second end cap **205** may be coupled to a cable with a jacket (not shown) that substantially surrounds the insert body **201**, first end cap **203**, and at least a portion of second end cap **205**. The jacket may further include a connection mechanism such as a threaded connector configured to secure two inserts **250** together. Thus, the inserts **250** are configured to be coupled and secured together such that the alignment adaptor **210** and at least a portion of both insert bodies **205** are enclosed in a sealed environment. In other words, liquid and/or gas cannot enter or exit the interface area between the inserts **250**. The inserts **250**

can be coupled together by any technique known in the art. The inserts **250** may be configured to couple to a bulkhead. In some embodiments, the inserts **250** may include a snap together or screw together connection. In some embodiments, the connector shells are configured to couple together and/or couple to a bulkhead. One or more seals or washers or other seal structures may also be included to ensure a pressure tight connection between two inserts **250**.

With reference now to FIG. **6**, an exploded view of the connector system **200** is illustrated. With the removal of the end cap **203** from the insert body **201**, a chamber **220** can be seen. Within the insert body **201**, a plurality of optical fiber holders **207** are spaced evenly apart about an internal diameter of the insert body **201**. However, more or less optical fiber holders may be included and the optical fiber holders may be positioned in any suitable manner within the insert body **201**. When assembled, the optical fiber holders **207** have one end at least partially disposed within the chamber **220**. The optical fiber holders **207** then extend through the insert body **201** and have an opposite end at least partially disposed within the second end cap **205**.

In the illustrated embodiment, a single equalizer tube **245** is positioned through the center of the insert body **201** and the single equalizer tube **245** is surrounded by the optical fiber holders **207**. However, more or less equalizer tubes may be used. In some embodiments, an equalizer tube **245** is positioned in place of an optical fiber holder **207**.

The equalizer tube **245** includes a lumen **237** extending therethrough. When assembled, one end of the equalizer tube **245** is at least partially disposed within the chamber **220** and the other end of the equalizer tube **245** is at least partially disposed within the second end cap **205**. In this way, the chamber **220** and connection face **225** of the second end cap **205** are in pressure communication. One of skill in the art will recognize that various solutions are available for providing a pressure communication link between the chamber **220** and the connection face **225** of an insert **250**. For instance, any passageway configured to provide a pressure communication link between the front face of an insert and a chamber in the insert may be used.

Continuing with FIG. **6**, the rear face **227** of the second end cap **205** can be seen. As shown, the second end cap **205** includes three fastener receiving openings **221**. The fastener receiving openings **221** may be configured to threadingly engage a fastener such as a screw. The second end cap **205** also includes a plurality of openings **205** therethrough. The openings are sized to receive at least a portion of an optical fiber holders **207** or equalizer tube **245**. The openings **205** and/or structure inserted therein are configured to prevent liquid and/or gas from passing through the interface between the opening **205** and structure inserted therein. Fluid and/or gas may only pass through the second end cap **205** via the lumen **237** in the equalizer tube **245** to and from the chamber **220**.

A system for further aligning fiber optic leads may or may not be used with the connector system **200**. As shown in FIG. **6**, the connector system **200** also includes an alignment adaptor **210**, a plurality of ferrules **213**, and a plurality of alignment sleeves **215** to further align the optical fibers. The alignment adaptor **210** includes a plurality of connection openings **218** and an equalizer opening **219** therethrough. The equalizer opening **219** provides a pressure communication link between the connection faces **225** of two inserts **250**.

The connection openings **218** are sized to receive an alignment sleeve **215**. In use, two complimentary fiber optic terminals come in contact with each other within the connection openings **218**. For explanation, a terminal end of an optical

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fiber exiting the connection face **225** of one insert may be at least partially surrounded by a ferrule **213** sized to receive the terminal end of a fiber optic lead. A terminal end of a second optical fiber exiting the connection face **225** of the opposing insert may be at least partially surrounded by ferrule **213** sized to receive the terminal end of a second fiber optic lead. The alignment sleeves **215** are configured to receive the ferrules **213**. Thus, a terminal end of a fiber optic lead the ferrules can be at least partially inserted into a ferrule. The ferrule **213** can then be inserted at least partially into an alignment sleeve **215** disposed within a connection opening **218** thus further ensuring the aligned connection of the terminals of two optical fibers. FIG. 7 illustrates the positioning of internal optical fiber holders **207**, equalizer tube **245**, ferrules **213**, and alignment sleeves **215** within the connector shell **205** and second end cap **205** according to some embodiments.

Moving on to FIG. 8A, a transparent perspective view of the insert body **201** is shown to further illustrate the insert body **201** and chamber **220**. The insert body **201** may include a first plurality of recesses **211** configured to receive fasteners to secure an end cap to the rear face **291** of the insert body **201** and a second plurality of recesses **212** configured to receive fasteners to secure an end cap **205** to the connection face **292** of the insert body **201**. As noted above, other means for securing the end caps to the insert body **201** may be employed.

The chamber **220** includes a plurality of generally cylindrical chambers **290** shaped to at least partially receive an optical contact body and/or equalizer tube. One or more seals may be positioned between the optical contact body and/or equalizer tube and the tubular chamber **290** walls. In this way, liquid and/or gas may not enter the interior of the chamber **220**. A spring or other biasing member may also be disposed with the cylindrical chambers **290** behind the optical contact body and/or equalizer tube positioned therein. The cylindrical chambers **290** may be configured to be in pressure communication with each other such that the entire chamber **220** is configured to have the same internal pressure. FIGS. 8A and 8B show that the insert body **201** includes radial passageways **229** that connect the cylindrical chambers **290** such that each chamber is in pressure communication even when an optical contact body and/or equalizer tube is disposed therein. The cylindrical chamber **290** running generally through the center of the insert body **201** may receive the equalizer tube while the remaining cylindrical chambers **290** may receive the optical fiber holders.

FIGS. 9A and 9B are enlarged views of an equalizer tube **245**. The equalizer tube **245** includes a lumen **237** extending therethrough. The equalizer tube **245** also includes recesses **600** configured to receive pressure seals near both ends of the equalizer tube **245**. The seals prevent liquid and/or gas from passing through the interface between the seal and the surface with which the seal is in contact with.

FIGS. 10A and 10B are enlarged views of an optical fiber holder **207**. The optical fiber holder **207** includes a chamber end **703**, a contact end **705**, and a body portion **707** therebetween. The body portion includes a window **255** therethrough. A lumen **701** extends through the optical fiber holder **207** from the window **255** to the contact end **705**. The optical fiber holder **207** also includes recesses **700** configured to receive pressure seals near both ends of the optical fiber holder **207**. The seals prevent liquid and/or gas from passing through the interface between the seal and the surface with which the seal is in contact with.

An optical fiber may be positioned within the window **255** and through the lumen **701**. In this way, a pathway is provided for the optical fiber to pass from the interior region of a

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connector to the interface between two connectors. After an optical fiber is inserted into the lumen **701**, a seal may be used to prevent liquid and or gas from passing through the lumen. In some embodiments the seal comprises an epoxy. The chamber end **703** of the optical fiber holder **207** may be positioned at least partially within a chamber and may abut against a biasing mechanism such as a spring.

A cross-sectional view of the connection system **200** is shown in FIG. 11A. FIG. 11B illustrates a cross-sectional view of the connection system **200** used to connect two fiber optic lines. As shown, springs **800** may be disposed within the chamber. Specifically, springs **800** may be located in the cylindrical chambers **290** that also include at least a portion of an optical fiber holder **207**. Thus, similar to the description concerning FIG. 3 above, the optical fiber holders are configured to slide within the cylindrical chambers **290**. The contact springs **800** may provide a force that presses the optical fiber holder **207** against each other when two connectors are mated. Furthermore, the lumen **237** within the equalizer tube **245** provides a pressure communication link between the chamber **220** and the connection interface area **810**.

With reference to FIG. 11B, a left optical fiber **801** enters the interior **230** of the connector through a window **235** in the insert body **201**. The optical fiber **801** then passes through a window in an optical fiber holder **207** and into the lumen **701**. The optical fiber **801** then passes through a ferrule **213** that is partially disposed within the optical fiber holder **207** and the alignment adapter **210**. A right optical fiber **802** enters the interior **230** of the opposing connector through a window **235** in the opposing insert body **201**. The optical fiber **802** then passes through a window in an optical fiber holder **207** and into the lumen **701** therethrough. The optical fiber **802** then passes through an alignment sleeve that is partially disposed within the optical fiber holder **207** and the alignment adapter **210**. Thus, the left optical fiber **801** and right optical fiber **802** are connected. The springs **800** provide a biasing force against the optical fiber holders **207** which is approximately constant because there is no pressure difference between the chambers of each insert **250** due to the sealed pressure communication link between the two chambers.

Of course, it is to be understood that not necessarily all objects or advantages may be achieved in accordance with any particular embodiment of the invention. Thus, for example, those skilled in the art will recognize that the invention may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other objects or advantages as may be taught or suggested herein.

Furthermore, the skilled artisan will recognize the interchangeability of various features from different embodiments. For example, the features of the connection systems disclosed in the various embodiments can be switched between embodiments. In addition to the variations described herein, other known equivalents for each feature can be mixed and matched by one of ordinary skill in this art to construct connection systems in accordance with principles of the present invention.

Although this invention has been disclosed in the context of certain embodiments and examples, it will be understood by those skilled in the art that the present invention extends beyond the specifically disclosed embodiments to other alternative embodiments and/or uses of the invention and obvious modifications and equivalents thereof. Thus, it is intended that the scope of the present invention herein disclosed should not be limited by the particular disclosed embodiments described above.

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The scope of protection is limited solely by the claims that follow. That scope is intended and should be interpreted to be as broad as is consistent with the ordinary meaning of the language that is used in the claims when interpreted in light of the specification and prosecution history and to encompass all structural and functional equivalents.

What is claimed is:

1. A connector comprising:  
a connection face;  
a chamber;  
at least one optical fiber holder having a first end positioned within at least a portion of an opening in the connection face and a second end positioned within at least a portion of the chamber, the at least one optical fiber holder including a lumen extending from the opening in the connection face to an opening in a lateral or transverse surface of the optical fiber holder;  
at least one biasing element configured to bias the optical fiber holder toward the connection face; and  
a means for preventing a pressure dependent force from acting on the second end of the at least one optical fiber holder.
2. The connector of claim 1, wherein the opening in the lateral or transverse surface of the optical fiber holder is positioned in between the connection face and the chamber.
3. The connector of claim 2, further comprising an optical fiber positioned at least partially within the lumen.
4. The connector of claim 3, wherein the optical fiber has an angled terminal end at least partially extending out of the opening in the connection face.
5. The connector of claim 3, wherein the optical fiber is sealed within the lumen.
6. The connector of claim 3, wherein no portion of the optical fiber is positioned within the chamber.
7. The connector of claim 2, further comprising a first seal between the first end of the optical fiber holder and the opening in the connection face and a second seal between the second end of the optical fiber holder and the chamber.
8. The connector of claim 2, wherein the optical fiber holder is longitudinally movable between a first position when the connector is not connected with another connector and a second position when the connector is connected with another connector.
9. The connector of claim 2, wherein the means for preventing a pressure dependent force comprises a pressure communication link between the chamber and the connection face.
10. The connector of claim 2, wherein the at least one biasing element is disposed within the chamber.
11. A connection system comprising:  
a first connector insert having a first connection face and first chamber in pressure communication with the first connection face;

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- a second connector insert having a second connection face and second chamber in pressure communication with the second connection face;
- at least one optical fiber holder having a first end at least partially positioned within an opening in the first connection face of the first connector insert and a second end at least partially positioned within the first chamber of the first connector insert, the optical fiber holder including a lumen extending from the opening in the first connection face of the first connector to an opening in a lateral or transverse surface of the optical fiber holder for the insertion of an optical fiber; and
- an outer shell configured to enclose the first connection face of the first connector and the second connection face of the second connector to form a pressure tight enclosure with the first chamber and the second chamber in pressure communication through the first connection face and the second connection face.
12. The connection system of claim 11, wherein the opening in the lateral or transverse surface of the optical fiber holder is positioned in between the opening in the first connection face of the first connector insert and the first chamber.
13. The connection system of claim 12, further comprising an optical fiber positioned at least partially within the lumen.
14. The connection system of claim 13, wherein the optical fiber is sealed within the lumen.
15. The connection system of claim 11, wherein the optical fiber holder is longitudinally movable between a first position when the first connector insert is not connected with the second connector insert and a second position when the first connector insert is connected with the second connector insert.
16. The connection system of claim 11, further comprising at least one second optical fiber holder having a first end at least partially positioned within an opening in the second connection face of the second connector insert and a second end positioned within the chamber of the second connector insert.
17. The connection system of claim 16, wherein the second optical fiber holder is longitudinally movable between a first position when the second connector insert is not connected with the first connector insert and a second position when the second connector insert is connected with the first connector insert.
18. The connection system of claim 17, wherein the second optical fiber holder includes a lumen extending from the opening in the second connection face of the second connector to an opening in a lateral or transverse surface of the second optical fiber holder for the insertion of an optical fiber.

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